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# Well Point Dewatering of Phosphatic Clays

By C. W. Smith and J. T. McLendon

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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## UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

| | | | |
|---|---|---|---|
| ft | foot | in | inch |
| $ft^3$/min | cubic foot per minute | pct | percent |
| gal/min | gallon per minute | r/min | revolution per minute |
| gpd/ft | gallon per day per foot | st/yr | short ton per year |
| h/d | hour per day | V | volt |
| hp | horsepower | | |

# WELL POINT DEWATERING OF PHOSPHATIC CLAYS

By C. W. Smith[1] and J. T. McLendon[2]

## ABSTRACT

The U.S. Bureau of Mines conducted research to determine the effect of ground water control on the dewatering of phosphatic clay wastes. Two storage impoundments were constructed. One impoundment was surrounded on three sides with a series of well points (shallow vertical wells) to lower the ambient water table and the second impoundment served as a control. Ground water was pumped from the area surrounding the test impoundment for a period of 490 days. A constant pumping rate of 60 gal/min resulted in a water table drawdown of 13 ft, approximating the bottom of the impoundment. At the end of the test period percent solids in the test impoundment was 35 pct, while in the control impoundment percent solids was only 26.8 pct. Percent solids of greater than 30 pct is required for capping and final reclamation using fertile overburden.

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## INTRODUCTION

Historically the storage and final disposition of clay fines generated by phosphate mining and processing has been an area of major concern to the phosphate industry and regulating agencies. A typical mine that processes 10,000,000 st/yr of matrix must handle about 2,800,000 st/yr of minus 150-mesh slimes that leave the washer at 1 to 4 pct solids. These slimes are impounded in earthen dams often as large as 800 acres and occasionally greater than 60 ft high (*1*).[3] These storage impoundments are generally perceived by the public as a potential source of environmental degradation should dam failures occur. Additionally, tremendous amounts of land area, estimated at over 75,000 acres in the central Florida area alone, are rendered useless for long terms in clay storage.

In response to these problems, the phosphate industry, State and Federal agencies, and private research groups have invested millions of dollars and thousands of worker hours toward a solution. Through steady and systematic efforts many partial solutions have been developed, however, no universal solution exists because of the extreme complexities of the problem (*2*).

A general consensus by the phosphate industry concluded that clays consolidated to 30 to 35 pct solids can be stored at or below natural ground level and can be satisfactorily reclaimed. At 35 pct solids, the clay solids develop a crustal surface that supports the use of light equipment and allows the site to be reclaimed with fertile overburden material. These clay solids, once consolidated, do not remix with rainfall, rather the solids retain their agglomerated state composed of discrete crustal segments.

Once a crustal surface develops on the clays, surcharging of the clay solids with overburden material (sandy topsoil) promotes continued dewatering of the clays by allowing the clays to drain through the sides and bottom of the containment structure. However, this added inducement is often mitigated by the hydrostatic pressures occurring at or below natural ground level as a result of the hydrostatic pressures produced by the water table. This opposing, inward acting pressure, retards the flow of drainage water at the interface of the structure. Consequently, a mechanism must be introduced that lowers the ground water table and subsequently decreases the hydrostatic gradient outside the impoundment structure, so that drainage flows from the impoundment to the surrounding surficial area.

To substantiate this hydrological consequence, a comprehensive investigation was undertaken by the U.S. Bureau of Mines to survey active and inactive clay impoundments. Extensive sampling of representative impoundments was made to correlate age of settling to degree of clay consolidation. From this study it was determined that clay slurries stored at or below the ambient water table contained clays less dense than those stored in above natural ground level impoundments (*3*). This indicated that settling of clays in below-grade impoundments was influenced to some extent by the surrounding water table. This implies that drainage of the impounded clays could be conducted through the sides and bottom of impoundments where a positive gradient exists inside the impoundment structure. To accomplish drainage from these structures, it is necessary to lower the ambient water table outside the impoundment to eliminate the opposition to flow of the impounded fluids.

In 1925, some of the earliest dewatering of the ambient water table was accomplished through the pioneering efforts of the Moretrench American Corp. (*4*). During pipeline construction, elevated water tables were often encountered along pipeline routes, which hampered excavation. However, these areas were successfully dewatered by inserting a series of well points (shallow vertical wells) along the pipeline to remove surficial water and to lower the localized water table, thus stabilizing the excavation. Well points were often installed vertically into place on 5- to 12-ft centers and were connected to a header pipe that subsequently was joined to a vacuum pump. The vacuum developed by the pump caused a suction lift at the well heads, which induced the flow of ground water to the wells. Under ideal conditions, the surrounding water table could be lowered as much as 20 ft below the datum plane (sea level).

This concept has been refined and employed in many other instances where geological and economical conditions permit. As an example, in October 1977, AMAX, Inc., used a modified system of well points to remove drainage from clay slurries stored in an aboveground impoundment located in the Central Florida Phosphate District.

In this system, shallow vertical wells (<20 ft deep) were placed along the toe of the impoundment structure and subsequently were connected to header pipes that surrounded a 10,000-ft-wide by 21,000-ft-long impoundment that was filled to a depth of 30 ft with phosphatic clay slurry. After evacuating the air from the piping system and the well point riser pipes, the effluent (water) from the clays was siphoned to a deep well injection point. At this point, the collected water flowed into a central well that channeled the water to a deep limestone aquifer. After the initial startup, this system operated continuously without additional power or pumping using only a siphoning action. This system operates freely until the vacuum in the system is disrupted.

[3]Italic numbers in parentheses refer to items in the list of references at the end of this report.

A similar drainage system has been employed on a routine basis by several phosphate mining companies to dewater small marshlands (perched water tables) areas prior to mining. Figure 1 shows a typical installation which uses an array of recharge wells drilled into the Floridan aquifer. These wells intersect, collect, and channel surficial water from the localized water table to the deep (350 ft) limestone aquifer. However, this practice of deep well injection of surficial water has been discontinued by authority of the Florida Department of Environmental Regulation (DER) because of the potential for contamination of major aquifers. At present, all drainage and injection wells discharging into aquifers must comply with drinking water quality standards and must meet many other basic design requirements.

Because much of the economics and feasibility of the well point system depends on deep well injection (via siphoning) of the effluent, these DER standards effectively prevent the discharge of untreated water into aquifers. However, for the purpose of this research investigation, a high-efficiency vacuum pump was substituted to simulate deep well disposal of well point fluids. The well point fluids (water) generated by this project were circulated via drainage ditches for use in the phosphate processing plant.

Based on a survey of prospective test sites, a research project was initiated by the Bureau at Agrico's Fort Green Mine in southwestern Polk County, FL, to investigate the effects of ground water control as it relates to impoundment drainage. Two impoundments were constructed. One impoundment was surrounded by a series of well points on three sides to lower the ambient water table while the second served as a control. This report summarizes the data obtained from this research effort.

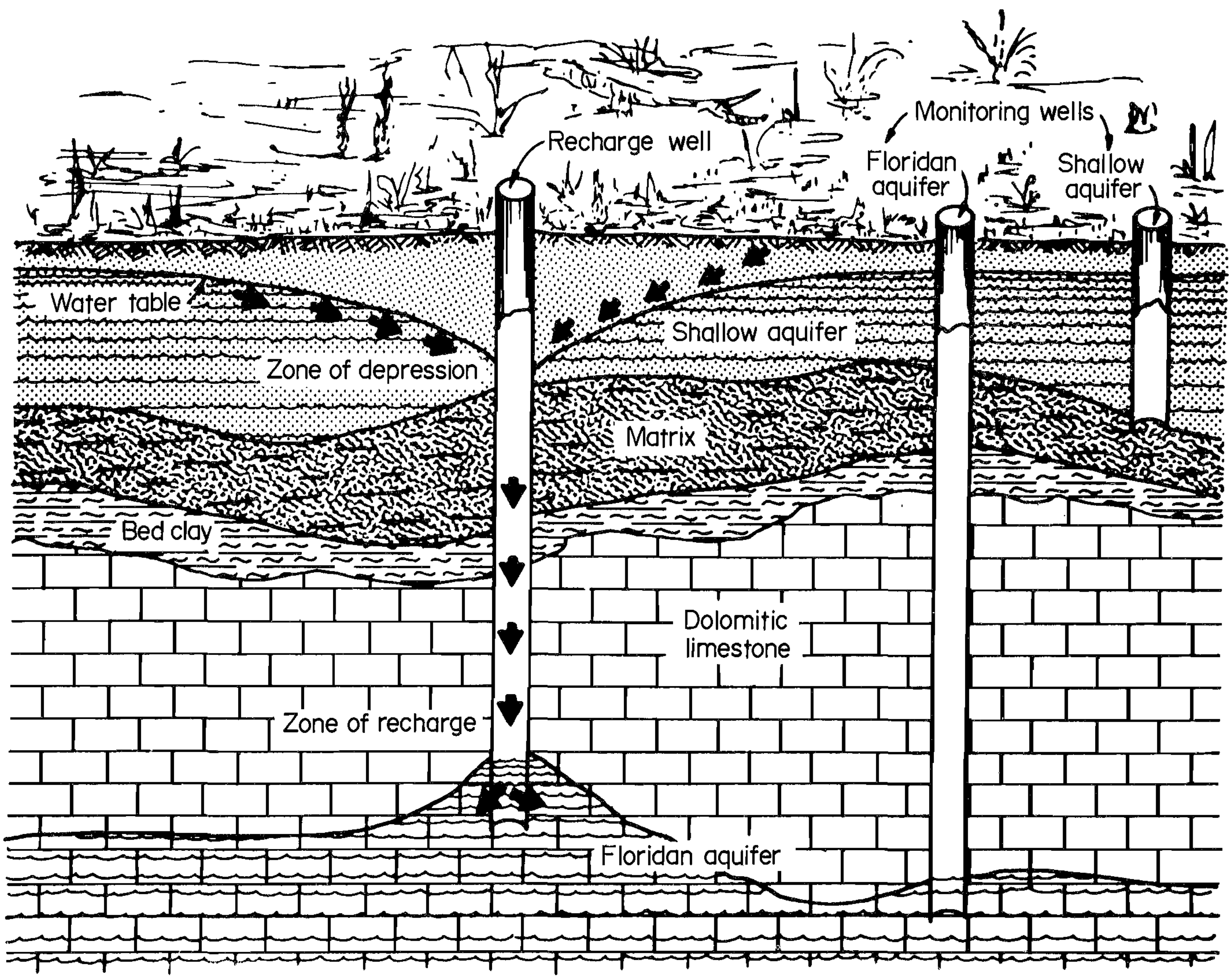


**Figure 1.–Recharge well system for draining marshland areas.**

## ACKNOWLEDGMENTS

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## DESCRIPTION OF WELL POINT DEWATERING

In order to explain the principles associated with well point dewatering, it is necessary to first define some of the terms and conditions relating to ground water. Ground water can be defined as water found underground in the saturated portions of porous rock strata and soils. Well point dewatering generally takes place in conditions of unconfined ground water. That is, ground water where the water table, or surface, is exposed to the atmosphere through openings in the overlying materials. The static water level or ambient water table is the level at which water stands in a well or unconfined aquifer when no water is being removed by pumping. Drawdown is defined as the difference, measured in feet or meters, between the water table and the pumping water level. These terms apply not only to actual pumping wells but also to surrounding observation wells.

When pumping begins, the water level in the area surrounding the pumped well is lowered with the greatest drawdown occurring in the well. Because the water level is lowest in the well, water flows toward the well from every direction to replace water being withdrawn by the pump. This movement of water creates a cone of depression in the water table surrounding the well. Each cone differs in size and shape depending upon the pumping rate, pumping duration, aquifer characteristics, slope of the water table, and recharge within the cone of depression of the well.

Two other concepts relating to ground water are useful in the design of dewatering systems. Transmissibility or transmissivity is defined as the ease with which water moves through a unit width of an aquifer. The transmissibility of an aquifer determines the amount of water that can be removed from a pumped well and is generally determined by conducting a pumping test. The standard units of measure in the United States system are gallons per day per foot. Transmissibility is used to determine well spacing, depths, and configurations for dewatering projects.

Storage release is another concept to consider in designing dewatering systems. To establish a dewatered condition, it is necessary to remove the water released by the aquifer. Some quantity of water must be pumped in addition to the steady state flow to achieve equilibrium. When transmissibility is high and the desired drawdown is considerable, this storage release of water can be quite high and consume considerable time, even months, depending on conditions.

Well point systems are groups of closely spaced wells, usually connected to a header pipe or manifold and pumped by suction lift. During operation, a central pump lifts water from each well by producing a partial vacuum in the header and riser pipes. The partial vacuum, or suction lift, that the pump can maintain determines the drawdown that can be obtained in the water-bearing formation. The maximum drawdown is the difference between the suction head and the static water level. In theory, suction lifts, limited by atmospheric pressure, up to 28.5 ft can be attained at sea level. In practice, maximum suction lifts of only 22 to 27 ft can be developed because of friction and other losses in the pump and piping system.

The diameter of well points used in dewatering systems is usually either 1.5 or 2 in, yielding maximum flows of 10 to 25 gal/min (*4*). Points are typically spaced 3 to 12 ft apart depending on the transmissibility of the saturated formation, the depth to which the water must be lowered, and the depth to which the points can be installed in the water-bearing formation (*5*). In general, closer spacings are required in finer grained soils.

A single well point installation is shown in figure 2. In each installation, a 4-in-diam hole was drilled to a depth of 24 ft. A 2-in-diam PVC pipe, fitted with a 4-ft section of slotted PVC screen, was attached to the lower end of the riser pipes. This section was inserted into the hole and the surrounding annulus between the hole wall and the vertical riser was back-filled with 1/2-in-diam washed quartz pebble. On the surface, a valve was placed between the vertical riser and the header pipe to isolate each well should the vacuum in the system be compromised. The vertical riser pipe of each installation was adjusted to the same elevation to insure equal suction lifts and to prevent short-circuiting of the vacuum system. The screen section in each installation also was placed in the lowest water-bearing zone. To complete the installation, a concrete cap was placed at the collar of each hole to seal the riser against incoming air and to prevent surface water contamination.

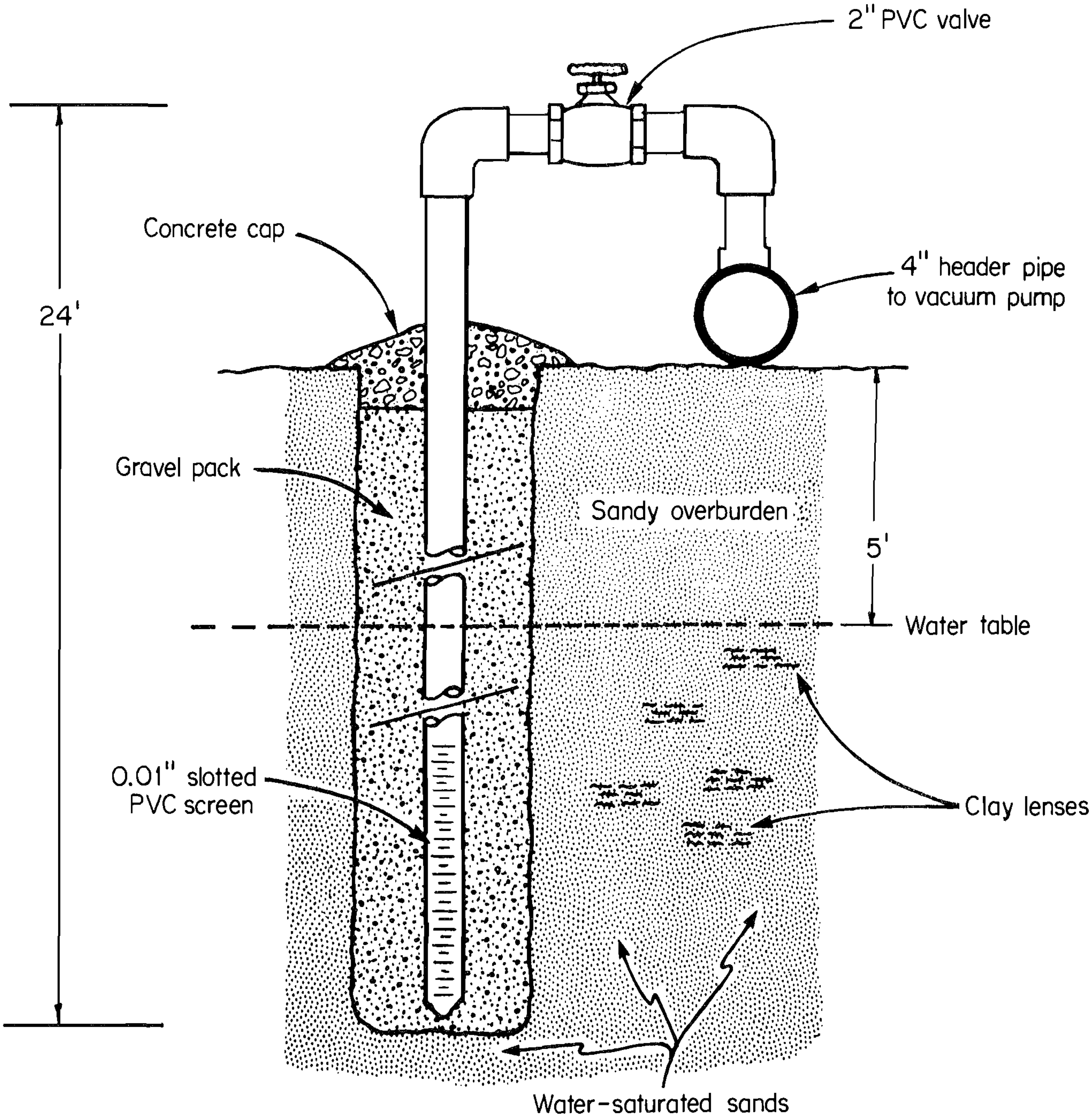


**Figure 2.–Cross section of typical well point installation.**

Figure 3 represents the conceptual well point dewatering system composed of well points, collector wells, and header pipes which were connected to an in-line injection well. The initial system contained a small vacuum pump for use in evacuating the air from the well points and piping system. Once a vacuum was established in the system, the pump was removed from the system and the incoming well point water allowed to siphon into a central well that subsequently channeled the flow of effluent (water) to the deep (350 ft) Floridan limestone aquifer. Because current regulatory standards prevent direct injection of surface water into deep seated aquifers, a high-efficiency vacuum pump was substituted to simulate deep well injection. Consequently, the discharge water from this system was directed to the processing plant in lieu of deep well injection.

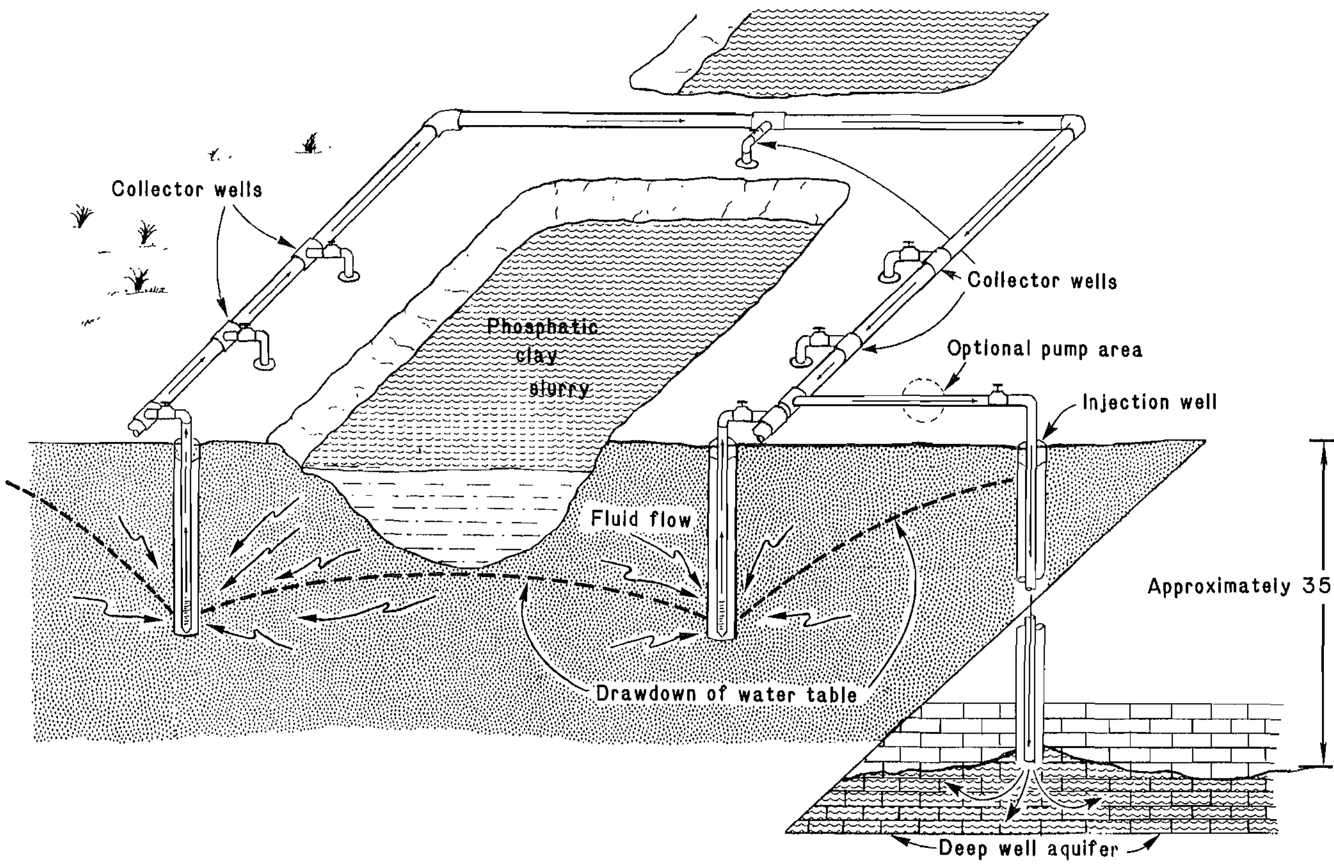


**Figure 3.–Conceptual well point dewatering system.**

Lowering the ground water level using a well point system involves creating a composite cone of depression. The wells must be spaced close enough that they overlap with each other and thus pull the water table down a certain distance at intermediate points between wells. Figure 4 illustrates how the overlapping areas of influence around three small wells produces an enhanced drawdown of the water table. The water table will remain at the level indicated as long as pumping is continued. Water drains by gravity from the formation above the lowered water table.

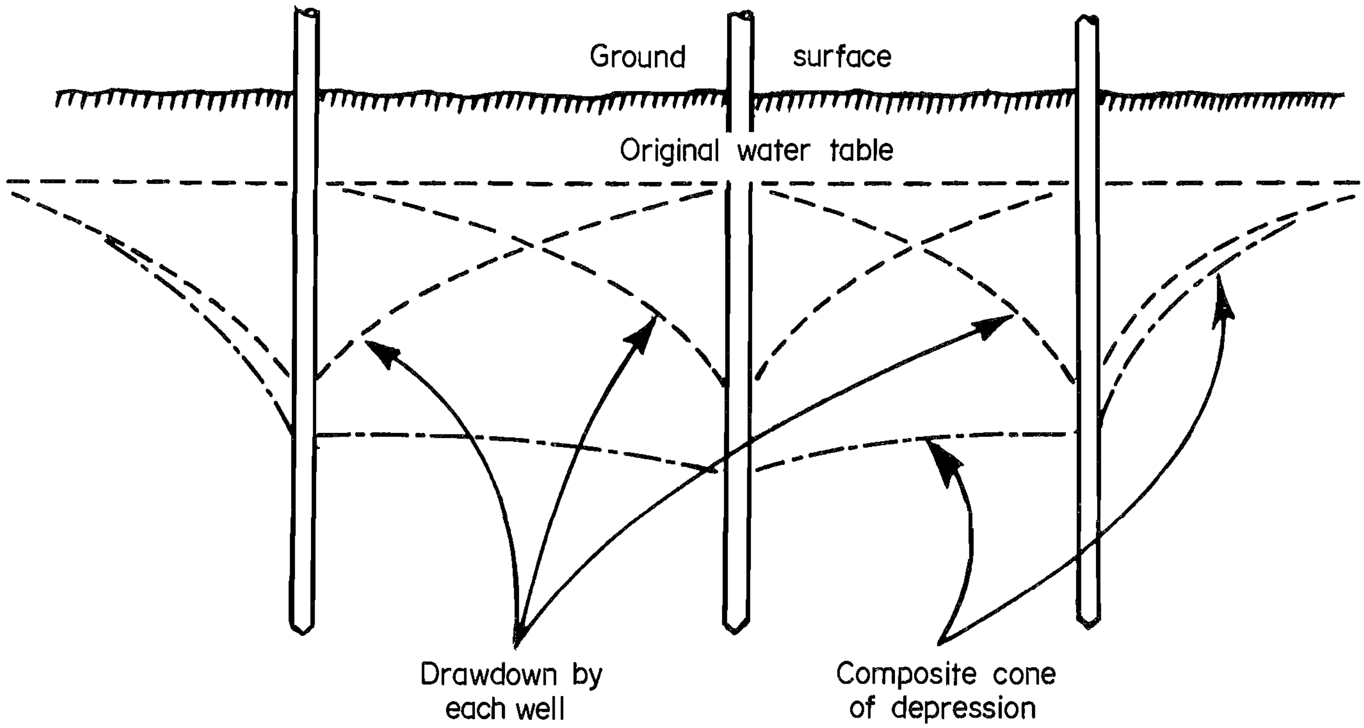


**Figure 4.–Effect of interference between wells.**

## DESCRIPTION OF TEST SITE

Two impoundments were constructed in an area consisting of parallel north-south trending windrows of spoil resulting from previous mining operations. The western perimeter of each impoundment consisted of undisturbed soil marking the westernmost extent of mining progress. The eastern perimeter of each consisted of disturbed soils comprising a windrow of spoil from previous mining. Three parallel dams were constructed to divide the area into two impoundments measuring approximately 60 by 125 ft and 17 ft in depth. Transmissibility of the disturbed soil in the dams and eastern perimeter was approximately 52 gpd/ft while that of the undisturbed soils in the western perimeter was approximately 525 gpd/ft. Ambient water table in the area is approximately 5 ft below ground surface. Discharge weirs were placed in each impoundment at a level corresponding to the ambient water table thus yielding approximately 12 ft of fluid and 5 ft of freeboard in each pond.

The southern impoundment was set up like a conventional settling pond and acted as a control throughout the experiment. The northern impoundment was set up as the test impoundment. A series of 48 well points were placed around the western, northern, and eastern perimeters of the pond. Ten well points spaced 10 ft apart were placed in the undisturbed soil along the western perimeter. Fourteen wells spaced 5 ft apart were placed in the northern dam and 24 wells spaced 5 ft apart were placed along the eastern perimeter. Closer spacings of the wells in the northern dam and eastern perimeter were required to maintain a lower water table because of the low transmissibilities of the disturbed soils.

Each well consisted of a 4-ft-long slotted PVC well screen with a 0.010-in opening connected to a 20-ft length of 2-in PVC pipe. Each well was connected to a 4-in PVC manifold leading to a vacuum centrifugal pump. Fourteen monitoring wells similar in design to the dewatering wells were spaced around the perimeter of both impoundments to monitor changes in the water table during dewatering. Figure 5 is a plan view of the test site showing the placement of the monitoring and dewatering wells.

Removal of ground water was achieved using a vacuum centrifugal dewatering pump. The pump was powered by a 18-hp, 440-V electric motor. The vacuum pump was of the oil seal type having a total displacement of 60 $ft^3$/min. At 1,460 r/min, water capacity was 120 gal/min at 31-ft total head.

## DISCUSSION OF TEST RESULTS

Slimes were conveyed to each of the ponds via an 8-in PVC pipeline from the flotation plant. Simultaneous stage filling of the impoundments was used to insure similar slurries in each pond. At the end of each stage of filling the slimes were allowed to settle and clear water was decanted from the surface using a combination of floating pumps and the discharge weirs. The decanted water was returned to the plant as process water. Filling of the impoundments was terminated when the slimes level reached the level of the discharge weirs and no further clear water could be removed from the surface. Percent solids of the slimes used to fill the impoundments varied from 1 to 4 pct with an average of approximately 2 pct determined through multiple samplings.

Changes in the water table due to pumping were initially monitored on a daily basis by checking the water level in each of the 14 monitoring wells. In later stages of the test, water levels were monitored every other day. Degree of consolidation of the slimes was determined on a periodic basis. Composite profiles of slimes from top to bottom were taken from nine sample stations in each pond and combined to determine average percent solids.

Ground water was pumped from the area surrounding the test impoundment for a period of 490 days. A constant pumping rate of 60 gal/min was maintained 24 h/d throughout the test period. A resultant drop in the water table from 5 to 18 ft below the ground surface occurred around the test impoundment. This level approximates the bottom of the impoundment. Figure 6 shows the drawdown versus time for the area surrounding the test impoundment. Approximately 60 days was required for removal of water from storage release as can be seen in this figure. Figure 7 is a cross section of the test impoundment showing the effects of pumping. Monitoring wells placed around the control impoundment showed a negligible change in ambient water table resulting from the pumping.

Table 1 presents the data obtained through sampling the test and control impoundments. Figure 8 presents the data in graphical form. Dewatering of waste slurries

**Table 1.–Sample dates and solids content for test and control impoundments, percent**

| Days from start | Test impoundment | Control impoundment |
|---|---|---|
| 0 | 2 | 2 |
| 122 | 12.5 | 11 |
| 143 | 18.2 | 12.1 |
| 199 | 22.4 | 15.9 |
| 241 | 24.6 | 18.4 |
| 290 | 26.6 | 21.2 |
| 380 | 31.3 | 24.3 |
| 450 | 33 | 26 |
| 490 | 35 | 26.8 |

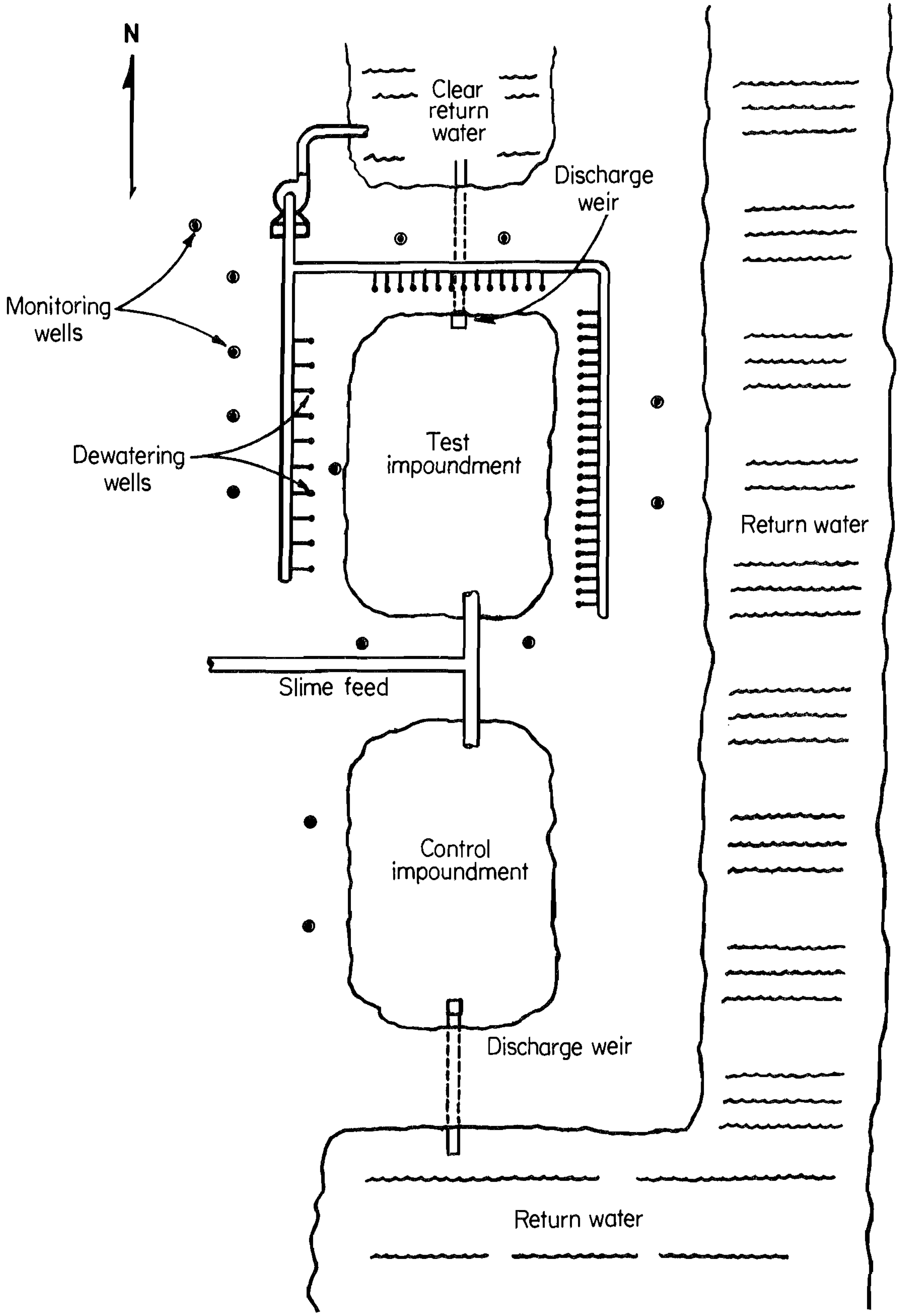


Figure 5.–Plan view of dewatering test site showing placement of wells.

occurred through two main components, drainage through the bottom and sides, and evaporation (*6*). Each of these components can be detected in figure 8. The clays in the control impoundment, which was placed in the water table, maintained pore fluid pressures equivalent to the surrounding soils. As a result, no drainage through the bottom or sides was possible. The slope of the line, which is a measure of the dewatering rate, remains nearly constant for the first 200 days. All dewatering in the control impoundment was a result of evaporation.

In contrast, the test impoundment exhibited a net positive pore pressure relative to the surrounding soils because of the lowered water table induced by pumping. This difference in pore pressure resulted in the flow of fluids from the impounded clays to the surrounding soils. In the initial stages of the test, dewatering proceeded through both drainage and evaporation components. At approximately 200 days into the test, the clays became sufficiently

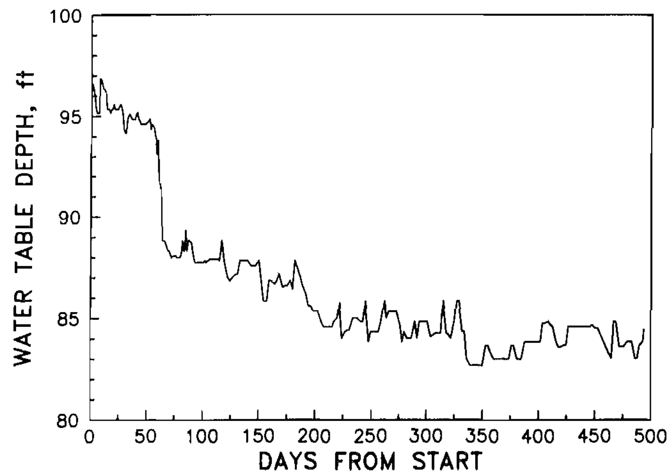


**Figure 6.–Drawdown versus time for water table surrounding test impoundment.**

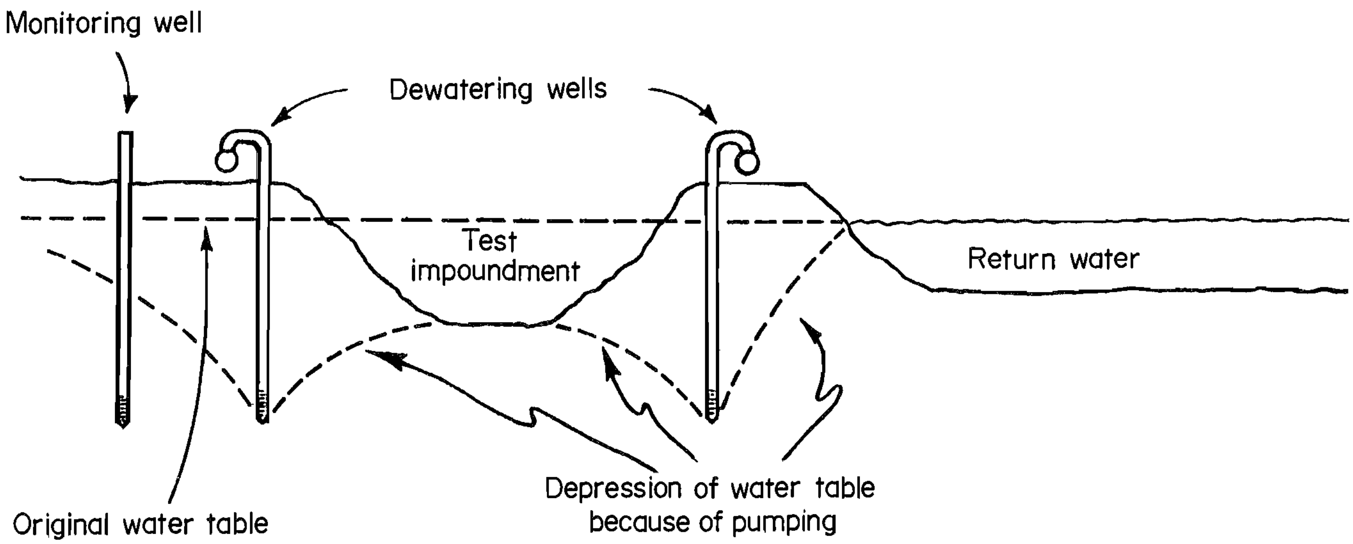


**Figure 7.–Cross section of test impoundment showing effects of pumping.**

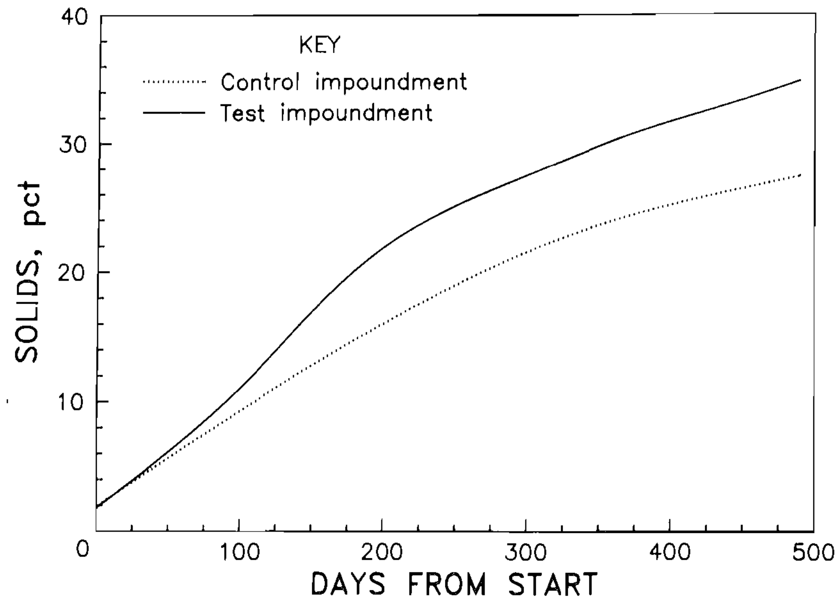


**Figure 8.–Percent solids versus time for test and control impoundments.**

densified to inhibit the permeability, therefore greatly decreasing the dewatering occurring through the drainage component and can be seen by the change in slope of the line at this time (fig. 8). At that point, pumping of ground water could be discontinued. After 200 days, evaporation became the major component of dewatering and the slope of the line was approximately that of the control impoundment. Although the drainage component did not contribute to dewatering throughout the test, it greatly enhanced the initial consolidation rate. At the end of the test period, percent solids in the test impoundment was 35 pct, while in the control impoundment, percent solids was 26.8 pct.

## CONCLUSIONS

Ground water control was shown to have a significant effect on the dewatering of phosphatic clays stored in impoundments below the ambient water table. Lowering the water table through the use of well points allowed for drainage of water from the phosphatic clays as well as evaporation. A series of 48 well points was used to lower the ambient water table surrounding a test impoundment containing phosphatic clays. At the end of 490 days, percent solids in the test impoundment was 35 pct. In contrast, percent solids in an identical control impoundment in the water table was only 26.8 pct. Percent solids of greater than 30 pct in the test impoundment allow for capping and final reclamation using fertile overburden materials, thereby returning the area to a more useful purpose.

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